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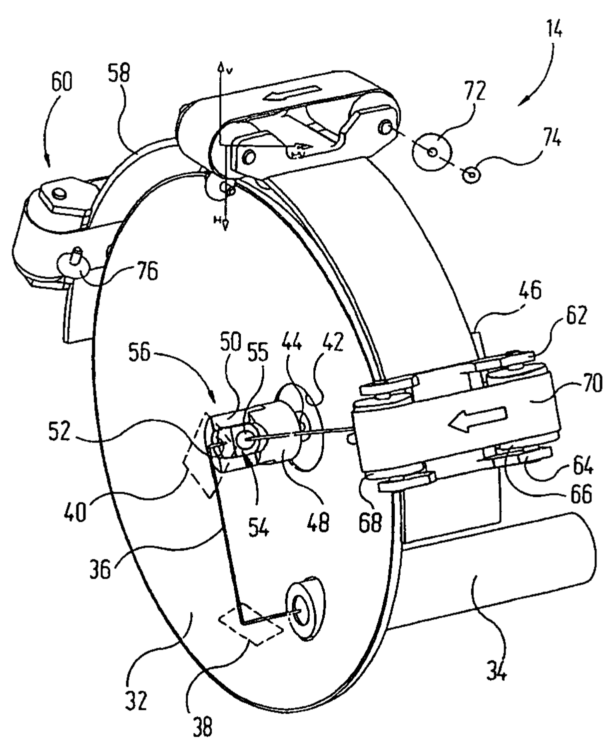

(57) Abstract: A scanning device for storage foils (12) comprises a scanning and transport unit (14) having a fast rotary deflecting element (54) to generate a reading light beam (36) rotating in a plane. A storage foil (12) arranged on a part-cylindrical support wall (28) is moved in axial direction by means of drive belts (70). Thus the storage foil is read along a helical line of small pitch.

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Device for reading flexible storage foils

The invention relates to a device for reading flexible storage foils in accordance with the preamble of claim 1.

Recently flexible storage foils are being used instead of X-ray films. When ionizing radiation or X-rays impinge on such foils, metastable storage centres will be produced, which are lattice defects or colour centres (or generally trap centers), which have trapped a charge carrier (electron or hole) produced by the ionizing radiation. Such storage centres are stable over long times. If the storage centres are illuminated with a very narrow laser beam of corresponding wave length, the storage centres will be moved into a higher excited state, from which the charge carriers can recombine under emission of light called photostimulated luminescence (PSL). The latter process is also shortly referred to as recombination of storage centers.

At such points of the storage foil, whereon a larger amount of X-rays has impinged, one obtains by reading this point using a reading light beam a higher amount of light quanta than at such points, which have received only a few X-rays. If the storage foil is scanned in two dimensions, the output signals of a light detector receiving the PSL corresponds to the optical density of a conventional X-film.

In known reading devices two dimensional scanning of the storage foil is obtained by arranging the storage foil on the outer surface of a drum, by rotating the drum and by moving a reading unit along a generating line of the drum, said reading unit including a laser

source and a light detector.

Such drum type scanners, which are also known for scanning images, are disadvantageous in that they have larger moving masses and in that the scanning velocity which can be achieved is only small due to this fact so that the scanning process takes a long time.

The object of the present invention is to provide a reading device in accordance with the preamble of claim 1, wherein the moving masses are smaller and which allows high scanning velocities and short scanning times.

In accordance with the invention this object is solved by a reading device having the features given in claim 1.

In a reading device in accordance with the present invention the storage foil support has the form of a part cylinder or of a cylinder, and a light deflecting element is arranged on the axis of this cylinder surface. This deflecting element produces a fine rotating reading light beam, which scans the interior surface of the storage foil. This light deflecting element requires only very small dimensions and is of small mass, only. Due to this construction the reading device in accordance with the present invention can well work with higher speed or rpm.

Further advantageous improvements of the invention are given in the subclaims.

If in accordance with claim 2 a pentaprism is used as the deflecting element for the reading light beam, one obtains a particularly precise deflection. The reflection of the reading light beam is exactly at 90° with respect to the

axial direction of irradiation and into a radial measuring direction not withstanding whether the prism is exactly aligned or not. Also play of a bearing journalling a prism carrying shaft has no influence on the deflection of the reading light beam. Thus motors of simple construction showing some play of the shaft can be used for rotating the light deflecting element without impairing the precision of the deflection of the light.

The improvement of the invention in accordance with claim 3 allows to use the light deflecting element also for focussing the reading light beam onto the interior surface of the storage foil.

In a reading device in accordance with claim 4 there is a reading light source which already per se provides a reading light beam of very small cross section and small divergence. This makes it possible to construct the light deflecting element as a very small component.

The further improvement of the invention in accordance with claim 5 is advantageous in view of a compact structure of the reading device and makes it possible to arrange the reading light source also at a distance from the axis of the cylindrical surface.

In a reading device in accordance with claim 6 both mirrors, which deflect the light, which is provided by the laser on an axis being parallel to the axis of the support surface, exactly onto the axis of the support surface, are in fixed relative position since the two deflecting mirrors are part of a single rigid optical element. This is advantageous in view of reducing the adjusting steps.

The further improvement in accordance with claim 7 is advantageous in that only a single deflecting mirror is necessary to provide an incoming laser beam on the axis of the foil support.

The improvement in accordance with claim 8 has the advantage that the reading light beam of a semiconductor laser diode has a circular cross section which results in pixels of the scanned image which have equal dimension in the two scanning directions.

The improvement of the invention in accordance with claim 9 is advantageous in view of utilizing as much of the fluorescence light as possible. A further advantage resides in the fact that the efficiency in detecting fluorescence light, which is emitted along the scanning circle by the storage foil, is constant. Thus no subsequent corrections of the detected fluorescence signals are necessary.

In a device as claimed in claim 10 the light detector may have a smaller radius so that the costs for the detector are smaller. In spite of this advantage the light generated at a larger radius can still be used due to the annular mirror reflecting this light onto an opposing mirror which will then reflect the light into the light detector.

The improvement of the invention defined in claim 11 is also useful in view of using as much of the fluorescence light as possible, which light is emitted by the storage foil after illumination with laser light.

In a device in accordance with claim 12 the light deflecting element can be driven directly without an in-

termediate direction changing gear by a motor that is arranged behind or in the mirror opposing the light detector.

In this respect the improvement of the invention in accordance with claim 13 is advantageous in that also such light is guided to the light detector, which impinges onto the mirror under large angles (grazing impingement). Thus the detection efficiency for fluorescence light is increased. Since the measured intensity of the fluorescence light is proportional to the intensity of the laser light as well as proportional to the detection efficiency, one can reduce the intensity of the laser light and still obtain the same sensitivity of demeasuring system. This is advantageous in that low cost laser light sources can be used.

Using the improvement of the invention in accordance with claim 14 will allow that the mirror opposing the light detector can also serve as an absorbing layer for reading light. Thus undesired reflections of the laser light can be avoided, which could result in storage centres lying in regions of the foil, which are not yet to be scanned, being already caused to fluoresce. This would result in worse resolution of the image. Also the contrast of the storage foil would be noticeably impaired.

The geometry of the mirror given in claim 15 is advantageous in that the mirror can have a large radial extension without having large axial extension and without requiring thin wall sections in the radial outward portion thereof. Also transport means provided to feed the storage foils across a reading gap defined by the foil support, can be arranged close to the axial end of the mirror which is advantageous in view of precisely

advancing the storage foil in axial direction at the location of the reading gap.

In a device as claimed in claim 16 reflected light will not travel in circumferential direction for a longer time but will be diffusely reflected to the light detector.

If the mirror is a cast component as set forth in claim 17, the optical surfaces of the mirror can be already provided in the casting process. These surfaces need no or very little final treatment.

The further improvement of the invention in accordance with claim 18 is advantageous in still further reducing the amount of reading light which reaches the light detector.

The further improvement of the invention in accordance with claim 19 is also useful in that as much of the fluorescence light as possible is detected by increasing the overall detecting surface. Thus a maximum amount of fluorescence is made available for the production of electric signals.

Claims 20 and 21 relate to solutions for driving the light deflecting element in a way that the light deflecting element and the drive motor associated thereto require only little space.

In a device in accordance with claim 22 PSL originating from the scanning circle (intersetion of the plane of rotation of the reading light beam and the light sensitive interior surface of storage foil bent to clyindrical or part cylindrical geometry) is used for generating an electric signal in both half spaces, i.e. on both sides

of the plane of rotation of the reading light beam.

The improvement of the invention in accordance with claim 23 is advantageous in view of keeping away reading light from the detector. In addition undesired reflections of reading light are avoided, which could read the storage foil at other points distant from the actually scanned point and which could thus result in faulty reading of the storage foil.

The improvement of the invention in accordance with claim 24 is particularly advantageous in that the storage foil to be read out is arranged on the outer surface of the foil support member. In spite of this fact the reading light beam has complete access to the interior surface of the storage foil throughout 360°.

The improvement of the invention in accordance with claim 25 allows very simple arranging of the storage foil on the foil support, the force generated in the elastically bendable storage foil warranting a snug contact of the storage foil on the support surface of the foil support. This is advantageous in view of reducing imperfect definition or sharpness of the image which may result from unprecise radial positioning of the storage foil outside of the focussing circle of the reading light.

In a device in accordance with claim 26 there is still better protection of the light detector against ambient light.

If the light blocking brush element is formed as set forth in claim 27, movement of the storage foil through the light barrier formed by the brush element is possible

under small friction and thus small wear.

Claims 28 and 29 relate to advantageous solutions for keeping the storage foil in safe surface contact with the supporting surface of the foil carrier without mechanically affecting the front side of the storage foil which is prone to formation of scratches.

Claim 30 gives a solution as to providing the axial movement of the storage foil with respect to that transverse plane wherein the reading light beam rotates in a simple manner.

The improvement of claim 31 is useful in that the danger of tilting of the storage foil under the influence of the transport means acting in axial direction is eliminated.

The improvement of the invention in accordance with claim 32 is advantageous in view of a good and reliable frictional contact between the transport means and the storage foil.

The improvement of claim 33 results in a large area of contact between the transport means and the storage foil such that uncontrolled slip between the transport means and the storage foil is avoided.

A reading device as claimed in claim 34 is useful in that no reading light can escape. Furthermore no ambient light can reach the light detector without being attenuated.

The improvement of the invention in accordance with claim 35 warrants that reading light, which possibly transverses the storage foil (in the case of a storage foil having no absorbing back layer) or which otherwise

reaches the shielding member or a foil guiding member, will be absorbed and will not be reflected back to the storage foil, which might again result in faulty reading as has been pointed out above. The indicated construction of the shielding member and/or the foil guiding member allows to use also such storage foils which do not include a back layer absorbing the reading light.

The device in accordance with claim 36 allows feeding of small storage foils, e.g. storage foils replacing conventional dental intraoral X-ray films directly to the working run of the axial drive means without exerting special diligence.

In the device as claimed in claim 37 positioning of the small storage foils is made at a point close to the input end of the axial drive means. So no misalignment may occur on the way between the positioning means and the input end of the second drive means.

The improvement claimed in claim 38 allows tactile positioning of the small storage foils.

In a device as claimed in claim 39 there is a smooth transition between the positioning means and the support surface of the foil support.

In a device as claimed in claim 40 a plurality of small storage foils can be read out simultaneously.

Measuring the angular position of the read out light beam using a mechanical or optomechanical position encoder would mean a very costly encoder considering the desired resolution of the image. Also this encoder would have to measure the angular position at a high measur-

ing rate. In accordance with claim 41 a reliable and precise signal being representative for the angular position of the reading light beam is obtained using simple mechanical and electronic components.

In a device as claimed in claim 42 at least regions of the image(s) are rapidly stored in a memory. This allows pre-processing and rejection of signals which do not correspond to pixels of the desired image read in the device already before forwarding the image signals to a computer for further processing.

In a device as defined in claim 43 the actual dark current of the light detector is measured continuously. In accordance with the measured dark current a dark current threshold value can be set which is used in setting the image signals associated to image points receiving no light to zero.

In a device as in claim 44 the flux of data to be communicated to an external processor is reduced. This allows use of a relatively slow interface which is commercially available. Averaging of successive image signals is also advantageous in view of improving the signal to noise ratio.

In a device in accordance with claim 45 the number of image signals combined into an averaged signal can be varied. Normally high resolution of the image is required in connection with dental intraoral images which are of small size, while a somewhat reduced resolution is acceptable in connection with dental panoramic images. So the total amount of information to be handled by the electronics associated to the device is about the same in connection with panoramic images and intraoral images.

In a device in accordance with claim 46 adjustment of the extent of averaging is established automatically in accordance with the size of the foil to be scanned.

Recognition of the foil size is particularly simple in accordance with claim 47. If a small storage foil is recognized in the foil positioning means of the foil support the device is set into the high resolution mode.

The further improvement of the invention in accordance with claim 48 is also advantageous in view of reducing the flux of data communicated to an external processor.

In a device in accordance with claim 49 the image signals associated to a plurality of small size intraoral storage foils can be rapidly stored in an image signal memory of the device itself. Transfer of the image data to an external data processing unit can then be made at a smaller rate using a commercial interface.

In a device in accordance with claim 50 only those of the output signals provided by the light detector are used, which correspond to image points of the storage foils, while those portions of the output signals which correspond to positions of the reading point which are outside of the storage foils arranged on the foil support are discarded. Recognition of the edges of the storage foils can be simply achieved by detecting a succession of a given number of non zero image signals by the data reduction circuit.

In accordance with storage foils of different size or different nature it is desirable to vary the gain of the light detector. This can be achieved using a device in accordance with claim 51.

In a device as defined in claim 52 the gain of the light detector is automatically adjusted responsive to the size of the storage foil arranged on the foil support, the size being an indicator for the sensitivity of the storage foil and for the dose conditions during exposure.

In a device as defined in claim 53 the detector gain can be wholly or at least partially adjusted manually. This allows some basic adjustment of the detector gain in accordance with local scanning conditions and in accordance with the type of storage foils and optical densities a particular dentist or doctor prefers to use.

The device as in claim 54 is advantageous in view of the little space used by the device. Also there is some gravity feeding of the storage foils in regions, where there are no positive axial drive means.

The further improvement of claim 55 is advantageous in view of ease removal of read out storage foils.

In a device as in claim 56 the read storage foils are particularly easy to grasp.

Below the invention will be explained in more detail referring to the drawings. Therein

figure 1 is a perspective view of a scanner for reading storage foil seen from the loading side;

figure 2 is a perspective view of the scanner of figure 1 seen from the foil discharge side, an end wall of the housing being partially broken away;

figure 3 is a perspective view of a scanning and transport unit of the scanner shown in figures 1 and 2 as seen from the loading side;

figure 4 is a perspective view of the main parts of the scanning and transport unit of figure 3 shown in enlarged scale;

figure 5 is a transverse section of the scanning and transport unit of figure 3, the section being taken in the plane, in which the reading light beam rotates;

figure 6 is a still enlarged representation of the foil transport unit;

figure 7 is a perspective view of a detector unit of the scanner of figure 1;

figure 8 is a section through an optical component of the scanning and transport unit, which at the same time forms a filter, a mirror as well as a shielding element;

figure 9 is a lateral view of an optical wave guide carrying two light deflecting layers;

figure 10 is a schematic axial section through a modified scanning unit for use in a scanner for reading out storage foils;

figure 11 is an axial section through a still further modified scanner for reading out storage foils;

Figure 12 is an axial section through the sanning section

of a still further modified scanning unit;

Figure 13 is a block diagram of electronic circuitry for pre-processing and buffering signals output from a light detector of a scanner as shown in figures 1 to 12; and

Figure 14 is a side elevational view of a still further scanner.

Figure 1 shows a scanner generally shown at 10 for reading out an optical storage foil 12. The storage foil 12 has the form of a rectangular sheet and is made from a flexible plastics substrate, a large number of phosphor particles being evenly distributed and embedded into the substrate. Alternatively the substrate may be coated homogeneously with a large number of phosphor particles. The distance of the phosphor particles is very small to warrant high resolution of the storage foils. Typical mean distances between the phosphor particles are in the range of a few μm.

The phosphor particles are made from a storage phosphor material, e. g. an alcali halide or alcaline earth halide salt, which is appropriately doped (e. g. with heavy metal ions) such that upon exposure to ionizing radiation metastable storage centres are formed therein. The dope of the salt is chosen such that the storage centres have metastable states which can be populated by X-ray light, particularly such X-ray light which is used in medical diagnosis. Such metastable states are stable for periods ranging from some 10 minutes up to an hour. If laser light of appropriate wave length (e. g. red light) is irradiated into the metastable states of the storage centres, the metastable storage centres will be transferred into higher

excited states from which the charge carriers can recombine generating flourescence light (PSL). The PSL typically is blue light.

If the optical excitation of the excited colour centres is made using a reading light beam of very small cross section (10 μm to 50 μm), reading of the excited colour centres, the density of which corresponds to the intensity of the X-ray light, is also only local. If the flourescence light is transmitted to a light detector, e. g. a photo-mulitplier, one obtains an electric signal corresponding to the X-ray intensity in the considered measuring or reading point. By moving the reading beam across the storage foil in two mutually perpendicular coordinate directions one can obtain a X-ray image which has been converted into electric signals.

The scanner shown in figure 1 has a scanning and transport unit generally shown at 14 as well as well a detector unit generally shown at 16. The detector unit 16 is positively engaged and received in the scanning and transport unit 14.

Referring to figures 2 to 6 the scanning and transport unit 14 will now be described in detail. The scanning and transport unit 14 has a main housing body 18, the transverse cross section of which generally corresponds to the cross section of a gutter. Two vertical walls 22, 24 are formed integral with a bottom wall 20 extending parallel the longitudinal axis of the latter. The vertival walls 22, 24 include an angled shoulder 26 extending towards the median plane of the housing. The free ends of the shoulder 26 carry a semi-cylindrical support wall 28.

In the claims and the description of the present application the axis of the support wall 28 will also be shortly referred to as "the axis" of the reading device.

The end of the main housing body 18 being the front end in figure 2 is closed by a flush end wall 30.

In a region being closer to the exit end of the main housing body 18 the main housing body 18 carries an intermediate wall 32 having the form of a circular disk. The intermediate wall 32 in a lower portion thereof carries a rod shaped laser 34 providing a focused reading light beam 36 of very small diameter. The rod shaped laser 34 extends parallel to the axis of the support wall 28, the laser axis thus being spaced from the axis of the support wall 28. Typically the diameter of the reading light beam 36 in the focus can be between 10 μm and 50 μm which corresponds to a resolution of the X-ray image, which is carried by the storage foil 12 in the form of correspondingly distributed metastable excited colour centres, being from 10 to 50 line pairs/mm.

As may be seen from figure 4, the reading light beam 36 is deflected onto the axis of the support wall 28 using two 45° deflecting mirrors 38, 40 which are carried by the main housing body 18 in a way which is not shown in detail in the drawings.

The intermediate wall 32 has a central shaft opening 42 receiving a motor shaft 44 of an electric drive motor 46 carried by the rear side of the intermediate wall 32. The motor shaft 44 carries a cylindrical prism carrying member 48, a quarter of which has been milled off as shown at 50.

A receptacle 52 formed in the prism carrying member 48 receives a pentaprism 54. The latter deflects the read out light beam 36 in radial direction. For focussing the read out light beam 36 to the interior surface of the storage foil 12 a collecting lens 56 is arranged on the exit surface of the pentaprism 54, e.g. by glueing the lens thereon to or by forming this lens integral therewith.

The components 36 to 54 described above co-operate to form a deflecting unit 56, which makes the reading light beam 36 rotate in a transverse plane also referred to herein as the beam plane or plane of rotation of the beam.

A semicylindrical narrow mounting member 58 carries three transport units generally shown at 60. These transport units each have two spaced opposing journalling walls 62, 64 each journalling one end of two rollers 66, 68, respectively. A transport belt 70 runs on the rollers 66, 68. The transport belt 70 is made from a material co-operating with the material of the storage foil 12 under high friction. The various transport units 60 each comprise a drive motor 72 carrying a position encoder 74. The various transport units 60 are electrically synchronized by means of a control unit not shown in figures 1 to 7.

A pressure roller 76 is associated to the radial inward working runs of the transport belts 70, respectively. The pressure rollers 76 are mounted at the interior surface of the support wall 28 for free rotation by means of journalling lugs 78, 80.

In the plane of rotation of the read out light beam 38 the support wall 28 is formed with a slot 82 exten-

ding in circumferential direction (see figure 2). Thus the read out light beam 36 reaches the light sensitive side of a storage foil 12 which contains the phospor particles. The storage foil 12 is arranged on the support wall 28 such that its sensitive side faces the axis of the support wall 28.

A shield wall 83 surrounds the transport units 60 being coaxial to the mounting member 58. The inward surfaces of the shield wall 83 are provided with a layer 85 absorbing the reading light. Thus it is possible, if desired, to also use storage foils which have no backing absorbing the reading light.

Scanning of the storage foil 12 using the scanning and transport unit 14 as described above is obtained as follows:

The storage foil 12 is arranged on the support wall 28 such that its storage layer faces in downward direction. The storage foil 12 is moved into the gap 84 defined between the mounting member 58 and the support wall 28 in a correspondingly curved state. In this gap the storage foil 12 is engaged by the working run of the transport belts 70, the pressure roller 76 warranting a pre-determined frictional contact between the convex rear side of the storage foil 12 and the transports belts 70. The transport belts 70 are driven in continuous manner and the drive motor 46 is energized. Consequently the storage foil 12 is scanned along a helical line in a continuous manner. The helical line has a width corresponding to the diameter of the read out light beam 36, a radius corresponding to the radius of the support wall 28 and a pitch corresponding to the speed of the transport belts and the rpm of the deflecting unit. The actual point at which the

read out light 36 hits the storage foil 12 (reading point) can be recognized from the output signals of a position encoder 47 associated to the motor 46 and of the position encoder 74.

The detector unit 16 serves for measuring the fluorescence light obtained at the respective actual reading points. As may be seen in more detail from figure 7, the detector unit 16 has a detector housing 86 including a bottom wall 88. Vertical walls 90, 92 are formed integral with the lateral edges of the bottom wall 88. The upper ends of the vertical walls 90, 92 carry inwardly extending shoulders 94 and a cylindrical support wall 96 as well as an end wall 98 closing the left hand end of the detector housing 86 as shown in the drawings.

One recognizes that the outer contour of the detector housing 86 is chosen so as to allow positive engagement of the detector housing 86 in the left hand portion of the main housing body 18.

A large diameter photomultiplier 100 is arranged in the support wall 96 such that its entrance window 102 is adjacent to the slot 82. A colour filter 104 is arranged across the entrance window 102, which filter is transparent for fluorescence light but blocks the reading light.

If the output signal of the photomultiplier 100 is recorded together with the output signals of the position encoders 47 and 74 one obtains an electric image of the X-ray image previously formed in the storage foil 12 in the form of exited metastable colour centers of the phosphor particles. This image can then be further processed electrically in view of changing the scale of reproduction, emphasizing

details, improving the signal/ noise ratia and so on. The X-ray image can also be put into an archive in its original and/or digitally processed form requiring only little space.

Once the storage foil 12 has been read out, it is entirely irradiated with erasing light to erase eventual remnant storage centers. Thereafter the storage foil can be used for taking a further X-ray image.

In order to be able to profit from the fluorescence light directed from the reading points into the right hand half space for measurement purposes, the intermediate wall 32 can be formed as a mirror. One way of doing so will now be described referring to figure 8.

A colour filter 106 is made from a material which is transparent for fluorescence light and absorbs reading light. A frusto-conical peripheral wall 107 of the colour filter carries a reflecting layer 108. A further reflecting layer 110 is arranged on the back side of the colour filter 106.

Alternatively the circumferential reflecting layer may be arranged on the exterior circumferential surface of the coulour filter 106 as shown at 108'. Thus this layer can be easily deposited together with the layer 110 and the reflected light will be filtered.

Due to provision of the colour filter 106 it is impossible that reading light after reflection will again impinge onto the light sensitive surface of the storage foil 12, which might result in faulty reading out of the storage foil as has been pointed out above. On the other hand fluorescence light, that originating from the actual

reading point is directed into the right hand half space as seen in the drawings, will be reflected into the entrance window 102 of the photomultiplier 100.

Figure 9 shows a one piece optical wave guide 112, which is of rod shaped geometry. The two ends thereof are provided with 45^{O} inclined end faces and on each of these two inclined end faces deflecting layers 114, 116 are provided. The one piece optical wave guide 112 thus can replace the two deflecting mirrors 38, 40 which facilitates mounting and ajusting of the scanning and transport unit.

In the modified embodiment in accordance with figure 10 components, the functions of which correspond to the function of components already discribed in connection with figures 1 to 10 have been given the same reference numerals. These components need not be described in detail below.

In the scanner of figure 10 the end wall 30 is replaced by the entrance window 102' of a further photomultiplier 100', opposing the photomultiplier 100 such that the overall arrangement is symmetric with respect to the plane of slot 82. The output signals of the two photomultipliers 100 and 100' are electrically added and are then further processed as has been described above in connection with photomultiplier 100.

A further modification of the scanner shown in figure 10 resides in the fact that the prism carrying member 48 has a turbine rotor 118 formed integral therewith. The turbine rotor 118 is exposed to an airjet discharged from the end of a pressure air passage way 120 formed in a transparent disk 122 overlying the colour filter

104 of the photomultiplier 100. An exhaust air passage way 124 is also formed in the disk 122. The exhaust air passage way 124 vents detended air discharged from the turbine rotor 118 to the atmosphere.

For measuring the position of the pentaprism 54 (shown in figure 10 in a simplified way as a mirror) a photo-diode 126 is provided being arranged in an angular region which is not covered by the storage foil 12. Upon each passage of the reading out light beam 36 the diode 126 provides a triggering signal for the control unit of the scanner. The actual momentary position of the reading out light beam 36 between two successive triggering signals is being interpolated from succeeding trigger pulses on a time basis.

In the embodiment shown in figure 11 components which are comparable to components already described above again carry the same reference numerals. These components are not described again in more detail. The storage foil 12 is arranged on the interior surface of a cylindrical support drum 128. The latter is movable in axial direction by means of a threaded spindle 130 driven by a drive motor 132. A position encoder 134 is associated to the drive motor 132.

Good contact of the storage foil 12 to the inward surface of the foil support 128 may be improved by perforating the peripheral wall of the foil support 128 as shown at 136. Behind the various openings 136 of this perforation there is an annular suction chamber 138 communicating with a vacuum source 140.

Deflection of the reading out light beam 36 is achieved in a way similar as described with reference to figures

1 to 7. When the drive motors 46 and 132 are simultaneously energized, the light sensitive surface of the storage foil will again be scanned along a helical line of very small pitch and, the output signal of the photomultiplier 100 will be recorded together with the signals output from the position encoders 47 and 134.

One recognizes that in the scanner of figure 11 reading of the storage foil can be achieved along the entire circumference of the foil support 128, while in the embodiment of the preceeding figures reading out of the storage foil is carried out over an angle of 180°.

Furthermore in the embodiment of figure 11 an annular mirror 142 is arranged on that end of the support wall 96 receiving the photomultiplier, which is adjacent to the slot 82. The annular mirror 142 is formed with a frusto conical reflecting layer 144. This is advantageous in view of capturing also fluorescence light which propagates in a direction being essentially perpendicular to the axis of the device.

In the above description of various scanners it has been supposed that these scanners are used for scanning large size storage foils, i. e. storage foils as they are used for taking panoramic images of the jaws or medical surview foils having a size of say 20 x 30 cm.

The scanners described above can also be used in connection with small storage foils having a size corresponding to the size of classic X-ray films used for taking intraoral images, i.e. say 3 x 4 cm.

In order to facilitate aligned positioning of such small storage foils the supporting wall 28 is formed with

three positioning recesses 146 being aligned in axial direction with an associated one of the transport belts 70. The positioning recesses 146 are provided immediately adjacent to the plane in which the reading light beam rotates. Each positioning recess has an inclined bottom wall 148 ascending torwards the plane of rotation of the reading light beam 36. The peripheral contour of each of the positioning recesses 146 corresponds to a rectangle.

The actuating member of a micro-switch 150 projects through a small opening of the bottom walls 148, respectively. The micro switches 150 output a signal indicating that a small storage foil has been placed in the corresponding positioning recess. This output signal is used for switching the electronics of the scanner between different modes of operation as will be described below in more detail referring to figure 13.

In order to seal the reading gap of the scanning unit against ambient light, semi-circular brush elements 152, 154 are arranged at the upstream and downstream end of the shielding wall 83, respectively. As may be seen from the enlargement of figure 1, the brush elements 152, 154 comprise bristles 156, which are inclined in forward feed direction so that the storage foils can be moved past the brush elements under small friction.

Alternatively or in addition bristles may be provided which are carried by the support wall 28 and extend in radial outward direction being also inclined in forward feed direction.

While three transport belts 70 and three positioning recesses 146 are shown in the drawings in practical embodiments more or less than three such components may

be provided. In a preferred practical imbodiment four transport belts 70 and four aligned positioning recesses 146 are provided.

Synchronizing of the transport belts 70 can be achieved by mechanical positive coupling and/or electronic coupling. Electronic coupling means e. g. that the transport belts are driven by stepping motors which are driven by pulses received from a common control circuit. In a particularly preferred embodiment one such stepping motor may be provided to drive two transport belts by means of suitable gear units.

In the scanning unit shown in figure 12 components, functional equivalents of which have already been described in connection with figures 1 to 12 have been given the same numerals. These components will not be described in detail again.

The photomultiplier 100 used in the embodiment of figure 12 is of smaller diameter than the photomultiplier shown in figure 7, i.e, smaller than the diameter of the cylinder defined by the support wall 28. An annular mirror 158 receives the window end portion of the photomultiplier 100. The mirror face of the mirror 158 has an radially outward curved portion 160 and a radially inward curved mirror portion 162. Both mirror portions are of revolution, the mirror portion 160 being of large radius of curvature, while the mirror portion 162 has a smaller radius of curvature. Both mirror portions are part paraboloids of revolution.

The intermediate wall 32 has been replaced by a mirror 164 having two mirror portions 166, 168 of larger and smaller radius of curvature, respectively. The mirror

164 has a central opening 165 to receive a micromotor or a motor shaft driving the light deflecting element 56. Mirror portions 166, 168 again part paraboloids of revolution.

The mirror portion 160 has smaller radius of curvature than the mirror portion 166.

The rotary encoder 47 associated to the motor 46 is shown to comprise a slit disk 47a and a light barrier 47b. This sensor, in the embodiment of figure 12, is used for speed control of the motor 46, only, but not for detecting the rotary position of the reading light beam 36.

Mirror 158 is provided with a flange portion 170 receiving the window end portion of the photo multiplier 100.

In the lower portion of the annular mirror 158 a radial passageway 172 is provided which receives a short "circu" (circular beam) semi-conductor laser 174. The reading light beam provided by the latter in radial direction is deflected by a mirror 176 into the axis of the scanner. It will be rotated in the beam plane lying between the two mirrors 158 and 164 as described above.

The laser 174 is arranged in a housing 184 connected to axial studs 186, 188 of the mirror 164 by screws 190.

In the lower portion of the interspace between the two mirrors 158 and 164 there is provided a triggering photo diode 178 which will be hit by the reading light beam 36 once upon each revolution of the light deflecting element 56. This photo diode is used for measuring the actual rotary position of the pentaprism 54 and the light beam

36 as will be explained in more deatail below referring to figure 13.

The bodies of the mirrors 158 and 164 are provided with recesses 180 receiving pressure rollers 182 supporting the storage foils in radial inward direction when being moved by the transport belts 70. Thus a good frictional contact between the transport belts 70 and the outer surface of the storage foils is warranted.

As may be seen from an enlargement of figure 12 the surface 192 of mirror 158 is roughened so that a diffuse reflection of light is obtained. The surface 192 carries a coating 194 which is transparent for fluorescence light and absorbes reading light. The coating 194 may be chosen so as to have diffuse reflective properties for PSL light.

The surface of mirror 164 carries a similar coating. The surface of mirror 164 may be perfectly reflecting or it may be roughened similar to surface 192 to provide for diffuse reflection of PSL light.

Figure 13 is a schematic block diagram of the electronic circuitry associated to the scanning device.

In figure 13 lines supplying signals which serve for controlling operation of another circuit have been marked by an arrow.

The photomultiplier 100 (and eventually an opposing further photomultiplier 100') is energized by a controllable high voltage supply 196. The photo current output from the photomultiplier 100 is supplied to a signal forming circuit 198 which will shape, amplify and filter the signal output from the photomultiplier in analog technique.

The signal generated by the signal forming circuit 198 is digitalized in an analog to digital convertor 200. The output signal of the latter is processed by a threshhold circuit 202. The threshhold circuit 202 compares the signal received from the A/D convertor 200 to a threshhold signal received from a processor 204. If the signal received is smaller than the threshhold value the threshhold circuit will output a signal of value "0". If the received signal exceeds the threshhold signal the signal will be put through to the output.

The output of the threshhold circuit 202 is connected to an averaging circuit 206. The latter calculates the signal average taken over a predetermined number of succeeding image signals, the predetermined number being given by a control signal received from the processor 204. From this predetermined number of digital signals the averaging circuit 206 will output a single averaged signal. So the flux of data provided by the output of the averaging circuit 206 is only a given fraction of the incoming flux of data.

The signal output from the averaging circuit 206 is supplied to a switching circuit 208 controlled by the processor 204. The switching circuit 208 will supply those signals, which correspond to image points lying within the periphery of the storage foils arranged on the supporting wall 28 to a storing unit 210, while those signals, which correspond to regions of the scanning area which are outside the edges of the storage foils are directed to a dark current monitoring circuit 212. The latter will determine from the incoming signals an average dark current signal and an average noise signal of the dark current which signals are supplied to the

processor 204.

The triggering photo diode 178 is connected to the reset terminal "R" of a counter 214. A count terminal "C" of counter 214 is connected to an output of a free running clock 216. Thus the instantaneous contents of the counter 214 is indicative of the angular position of the reading light beam 36.

A second counter 218 has a count terminal "C" receiving pulses from a free running clock 219, the operational state (ON/OFF) and working frequency of which are controlled by the processor 204. The pulses provided by the clock 219 are used to control the three stepping motors 72 associated to the three transport belts 70 so as to synchronously cooperate with correpsonding portions of the storage foil being scanned.

The second counter 218 further has a reset terminal "R" receiving a signal when an end switch 220 cooperating with the axial drive unit for the storage foils is actuated. The end switch 220 may be a micro-switch or a light barrier or the like. Thus the actual contents of counter 218 is indicative of the axial position of a storage foil being scanned with respect to the beam plane (i. e. the plane in which the reading light beam 36 rotates).

The output signals of counters 214 and 218 are combined into a single addressing signal by juxtaposition or concatenation by a write address circuit 222. The latter is connected to write address terminals "WA" of a fast solid state read/write memory 224 (RAM). Data input terminals "DI" of the latter receive data from a write control circuit 226, the input of which is connected to the first output of the switching circuit 208.

A read address circuit 228 is controlled by the processor 204. Its output is connected to read address terminals "RA" of the memory 224.

Data output terminals "DO" of the memory 224 are connected to a read control circuit 230, the output of which is connected to a data line 232 which may be connected to an external computer used for further processing of the image data like enhancement of contrast, scaling, rotation of the image and the like.

The components 222 to 230 together form the storing unit 210.

The circuits 198 to 226 are clocked in accordance with clock signals of appropriate frequency, which are provided by the clock 216, which in addition to the output connected to counter 214 has further outputs of higher frequency not shown in detail. The circuits clocked by the clock 216 have been marked by a small cross in the upper left corner of the respective box. One recognizes that the image signal acquisition and storing of the image signals is at high speed in real time, while reading out image signals from the memory 224 may be achieved at a lower rate in accordance with the data transfer capacity of data line 232.

The processor 204 is connected to a monitor 234 and a keyboard 236 for controlling working of the scanning device and giving messages to a user. The processor 204 cooperates with a mass storage like a hard disk 238 and may be connected to a printer 240 for outputting images, if desired.

The processor 204 operates in accordance with programs stored on the hard disk 238 or in a ROM. Changes of its operation may be effected by entering commands and data via keyboard 236. Further means to modify the working of processor 204 are the micro-switch 150, the output signal of which informs the processor 204 on the kind of storage foils to be scanned. Normally the small storage foils for taking dental intraoral images are not only of different dimension but also of different sensitivity as compared to the large storage foils used for panoramic images. So in accordance with the signal output from the micro-switch 150 the processor 204 may not only know the edges of the storage foil and program the switching circuit 208 correspondingly, but the processor 204 may also program the high voltage output from the high voltage supply 196 in accordance with the sensitivity of the storage foil used such that the overall range of output signals received from the photomultiplier 100 essentially corresponds to the overall working range of the A/D converter 200.

A further input terminal of the processor 204 is connected to a manually adjustable signal source which has been presented by an adjustable resistor 242. This resistor may be used to define part of the control signal supplied to the high voltage supply 196 by the processor 204. By doing so the scanner is adjusted to local scanning conditions including stray light, type of storage foils used, type of photomulitplier used, optical densities preferred by the respective user and so on.

A further output terminal of the processor 204 controls the free running clock 219, the output signal of which is used for activating stepping motors 72-1, 72-2 and 72-3 associated to the three transport belts 70. Thus elec-

tronic synchronization of the three transport belts is achieved and the pitch of the helical scanning line or the distance beween successive scan lines is determined. The signal output from clock 219 is also supplied to the count terminal "C" of counter 218 as has been pointed out above.

Figure 14 shows a modified scanning device, which as to function is comparable to the one explained above referring to figures 1 to 7. Components being functionally equivalent to components already shown in this figures are given the same reference numerals, even if they differ in geometry.

The main differences between the embodyment of figure 14 and the embodyment of figures 1 to 7 resides in the fact that the supporting wall 28 and the main housing body 18 are of revolution and that the axis of the scanner if vertical. The main housing body 18 is carried by a horizontal base plate 246.

A storage foil capturing wall 248 of frustoconical geometry is provided under the scanning and transport unit 14. Thus storage foils 250 for taking small dental intraoral images are captured after leaving the scanning and transport unit 14. The axial dimension of the capturing wall is smaller than the length of the storage foils 250 so that the upper end of the discharged storage foils 250 can be easily grasped.

In a further emodiment not shown in the drawings the belt drives feeding the storage foil in axial direction may be replaced by friction wheels or friction rollers (or groups of such wheels or rollers arranged along generating lines of the cylinder surface defined by

the support wall 28) which are mechanically or electro-cally coupled for synchronous operation.

In the above description reference has been made to the storage foils as such. It is to be understood, that these storage foils are actually used together with foil holders or light tight one way envelopes. These components are removed before scanning of the latent images of the storage foils and are applied to the storage foils after reconditioning for further use (erasure of remnant storage centers).

Claims
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1. A device for reading flexible storage foils comprising a foil support (28; 128) being at least partially cylindrical, comprising fixing means (58; 136 to 140) for releasibly attaching the storage foil (12) to the foil support (28; 128), comprising a reading light source (34) providing a reading light beam (36) of small diameter the wave length of which is suitable to excite metastable storage centers of the storage foil (12), comprising first drive means (46) providing a first relative movement between the reading light beam (36) and the storage foil (12) which is in circumferential direction with respect to the cylinder axis of the foil support (28; 128), comprising second drive means to produce a second relative movement between the reading light beam (36) and the storage foil (32) which is in a direction being parallel to the cylinder axis of the foil support (28; 128) and comprising a light detector (100) being responsive to fluorescence light of the storage foil (12) generated by the reading light beam (36), characterized in that the foil support (28; 128) carries the storage foil (12) such that its light sensitive layer faces in radial inward direction, i.e. the light sensitive layer being bent to concave cylindrical geometry, and in that a rotating light deflecting element (54) is arranged on the axis of the foil support (28; 128) by which the reading light beam (36) is directed towards the storage foil (12).

2. The device as in claim 1, characterized in that the light deflecting element comprises a penta prism

(54).

3. The device as in claim 1 or 2, characterized in that the light deflecting element (54) carries a lens (55) focussing the reading light beam (36) onto the storage foil (12).

4. The device as in one of the claims 1 to 3, characterized in that the reading light source (34) is a laser.

5. The device as in claim 4, characterized in that the laser (34) is oriented parallel to the axis of the foil support (28; 128) and the beam (36) produced thereby is deflected into the axis of the foil support (28; 128) by a deflection mirror arrangement (38, 40; 114, 118) and is directed to the light deflecting element (54) along said axis.

6. The device as in claim 5, characterized in that the deflecting mirror arrangement comprises two mirror layers (114, 118) arranged in fixed relative position, said mirror layers being preferably carried by a one-piece optical wave guide (112).

7. The device as in claim 4, characterized in that the laser (34) is oriented perpendicular to the axis of the foil support (28; 128) and the laser beam produced thereby is reflected into the axis of the foil support (28; 128) and onto the light deflecting element (54) by means of a deflecting mirror (176).

8. The device as in one of claims 4 to 7, characterized in that the laser is a circu semiconductor laser.

9. The device as in one of claims 1 to 8, characterized in that the light detector (100) is of cylindrical geometry and has an entrance window (102), the radius of which essentially corresponds to the radius of the cylindrical surface of the foil support (28; 128).

10. The device as in one of claims 1 to 8, characterized in that the light detector (100) has a radius being smaller than the radius of the cylindrical surface of the foil support (28; 128) and that the entrance end of the light detector (100) is received in an annular mirror (158), the outer radius of which essentially corresponds to the radius of the support surface of the foil support (28).

11. The device as in claim 9 or 10, characterized in that a mirror (108, 110; 164) reflecting fluorescence light is provided which opposes the light detector (100) with respect to the transversal plane of rotation of the reading light beam (36).

12. The device as in claim 11, characterized in that said mirror (108, 110; 164) is formed with a hole (42; 165) receiving a motor shaft or the housing of a miniature motor.

13. The device as in claim 11 or 12, characterized in that the mirror (108, 110; 164) has a frusto-ellipsoid or frusto-parabolic deflecting layer (108).

14. The device as in one of claims 10 to 13, characterized in that the mirror comprises mirror layers (108, 110) which are provided on the circumferential surface

and the back surface of a colour filter (106), the colour filter (106) being transparent for fluorescence light and absorbing reading light.

15. The device as in one of claims 10 to 14, characterized in that the mirror (108, 110; 164) has a mirror surface formed by two merging surfaces of revolution, an radially outer one of which has a large radius of curvture, while the radially inward one of which has a smaller radius of curvture.

16. The device as in claims 10 to 15, characterized in that the mirror surface (192) of the mirror (164) is roughened to provide for diffuse reflection of light.

17. The device as in claim 16, characterized in that the mirror (164) is a cast component, preferably a cast aluminum or aluminum alloy component.

18. The device as in one of claims 10 to 17, characterized in that the mirror (108, 110; 164) has a mirror surface (192) being coated with a layer (194) being transparent to fluorescence light and absorbing reading light.

19. The device as in one of claims 1 to 18, characterized in that the light deflecting element (54) is driven by a motor (118) of small radial dimension,

20. The device as in claim 19, characterized in that the light deflecting element (54) is driven by a turbine rotor (118).

21. The device as in claim 19, characterized in that the light deflecting element (54) is driven by

the rotor of a miniature electro motor.

22. The device as in one of claims 1 to 19, characterized in that a second identical light detector (100') is provided which is arranged symmetric to the light detector (100) with respect to the plane of rotation of the reading light beam (36).

23. The device as in one of claims 1 to 22, characterized in that a colour filter (106) is arranged in front of the entrance window (102) of the light detector (100, 101'), said filter being transparent for fluorescence light and absorbing reading light.

24. The device as in one of claims 1 to 23, characterized in that the foil support (28) defines a slot (82) lying in the plane of rotation of the reading light beam.

25. The device as in claim 24, characterized in that a guide member (58) is arranged so as to surround the foil support (28) at small distance so that a gap (84) defined between these two components positiones the storage foil in radial inward and outward directions.

26. The device as in claim 25, characterized in that at least one strip shaped brush element (152, 154) is arranged at the gap (84) defined between the foil support (28) and the guide member (58) surrounding the latter.

27. The device as in claim 26, characterized in that bristles (156) of the brush elements (152, 154) are inclined in forward foil feed direction.

28. The device as in one of claims 1 to 27, characterized in that the fixing means (128) comprises suction openings (136) merging into the support surface of the foil support (28).

29. The device as in one of claims 1 to 28, characterized in that the fixing means is at least partially formed by magnetic material being provided on at least part of the support surface of the foil support (28), magnetic fixing elements being adapted to be positioned above the storage foil (12).

30. The device as in one of claims 1 to 29, characterized in that the second drive means include at least one drive element (70) frictionally co-operating with the storage foil (12).

31. The device as in claim 30, characterized in that the second drive means comprise a plurality of drive elements (70) being arranged under equal circumferential distance.

32. The device as in claim 30 or 31, characterized in that pressure means (66, 68; 180) are provided warranting a pressure contact between the drive element (70) and the storage foil (12).

33. The device as in one of claims 29 to 31, characterized in that the drive elements comprise drive belts (70) or at least one friction wheel or friction roller.

34. The device as in one of claims 24 to 33, characterized in that the reading slot (82) is surrounded by a shielding element (83).

35. The device as in claim 34, characterized in that the inward facing surface of the shielding member (83) and/or of a storage foil guiding element (58) are provided with a layer (85) absorbing reading light.

36. The device as in one of claims 1 to 35, characterized in that the foil support (28) is formed with at least one positioning means (146) adapted to position a small storage foil in circumferential direction of the support means (28), said positioning means (146) being axially aligned with the second drive means.

37. The device as in claim 36, characterized in that said positioning means (146) are arranged adjacent to the plane of rotation of the reading light beam (36).

38. The device as in claim 36 or 37, characterized in that the positioning means are formed by shallow recesses (146) formed in the outer surface of the foil support (28).

39. The device as in claim 38, characterized in that a bottom wall (148) of the positioning recess (146) is inclined in such manner that its axially downstream end is flush with the surface of the foil support (28).

40. The device as in one of claims 36 to 39, characterized in that the second drive means comprise a plurality of transport belts (70) being arranged under equal circumferential distance and that for each of said transport belts (70) an aligned positioning means (146) is provided.

41. The device as in one of claims 1 to 40, characteri-

zed in that a triggering light sensitive element (178) is arranged in the plane of rotation of the reading light beam (36) providing a triggering signal to a counter (214), a count terminal (C) of which is connected to a free running clock (216), the output of the counter representing the output of an angular position encoder associated to the first drive means (46).

42. The device as in one of claims 1 to 41, characterized in that the output signal of the light detector (100) is fed to a memory (224) being addressed by the output signals of position encoders (214, 218) associated to the first and second drive means.

43. The device as in claim 42, characterized in that output signals of the light detector (100) associated to angles of the reading beam (36) where the reading beam (36) does not hit a portion of the storage foil (12) are used to calculate (212) a dark current threshold value and in that a threshold circuit (202) sets all signals equal to zero which are smaller than the thus calculated threshold value.

44. The device as in claim 42 or 43, characterized in that the image signals are supplied to an averaging circuit (206) combining a given number of succeeding image signals into an averaged image signal which is supplied to the image signal memory (224).

45. The device as in claim 44, characterized in that control means (150; 236) are provided for determining the number of image signals to be combined by the averaging circuit (206), respectively.

46. The device as in claim 45, characterized by a storage

foil size sensor (150), the output signal of which is used for controlling the number of averaged signals.

47. The device as in claim 46, characterized in that the storage foil size sensor (150) is a sensor responding to presence of a small storage foil in small foil positioning means (146) provided in the foil support (28).

48. The device as in one of claims 42 to 47, characterized in that said image signal memory (224) is a fast storing memory and that a read out circuit (230) is associated to this memory which will output the signals contained in such memory at a smaller rate than the reading rate.

49. The device as in claim 48, characterized in that the image signal memory (224) has a capacity corresponding to the entity of image signals received from small storage foils arranged on the foil support (28).

50. The device as in one of claims 42 to 49, characterized in that the image signals are supplied to the image signal memory (224) by means of a data reduction circuit (208) being responsive to the position of the edges of a storage foil, which fact is recognized e.g. by a succession of a plurality of image signals being larger than the threshold value, the data reduction circuit discarding image signals corresponding to reading points being outside the edges of the storage foils.

51. The device as in one of claims 1 to 50, characterized in that the light detector (100) is a controllable gain light detector and control means (204) are associated thereto to manually or automatically set the

detector gain.

52. The device as in claim 51, characterized in that the gain of the light detector (100) is at least partially set using the output signal of a storage foil size sensor (150).

53. The device as in claim 51 or 52, characterized by manual input means (242) for at least partially determining the detector gain.

54. The device as in one of claims 1 to 53, characterized in that the axis of the foil support (28) is oriented in vertical direction.

55. The device as in claim 54, characterized in that storage foil capturing means (248) are arranged at the foil output side of the foil support.

56. The device as in claim 55, characterized in that the foil capturing means (248) comprise at least one collecting surface being inclined with respect to the vertical direction.

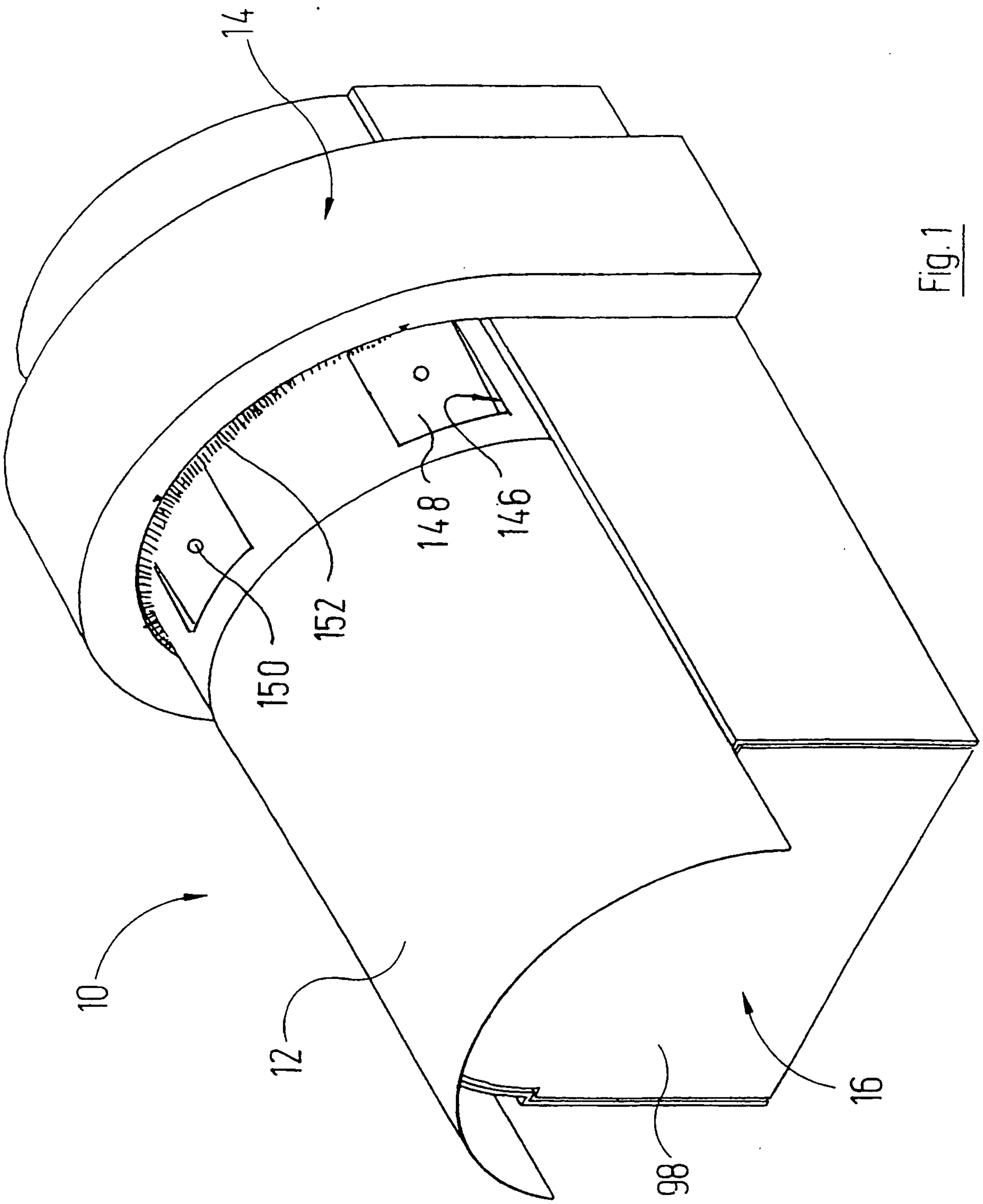

Fig.1

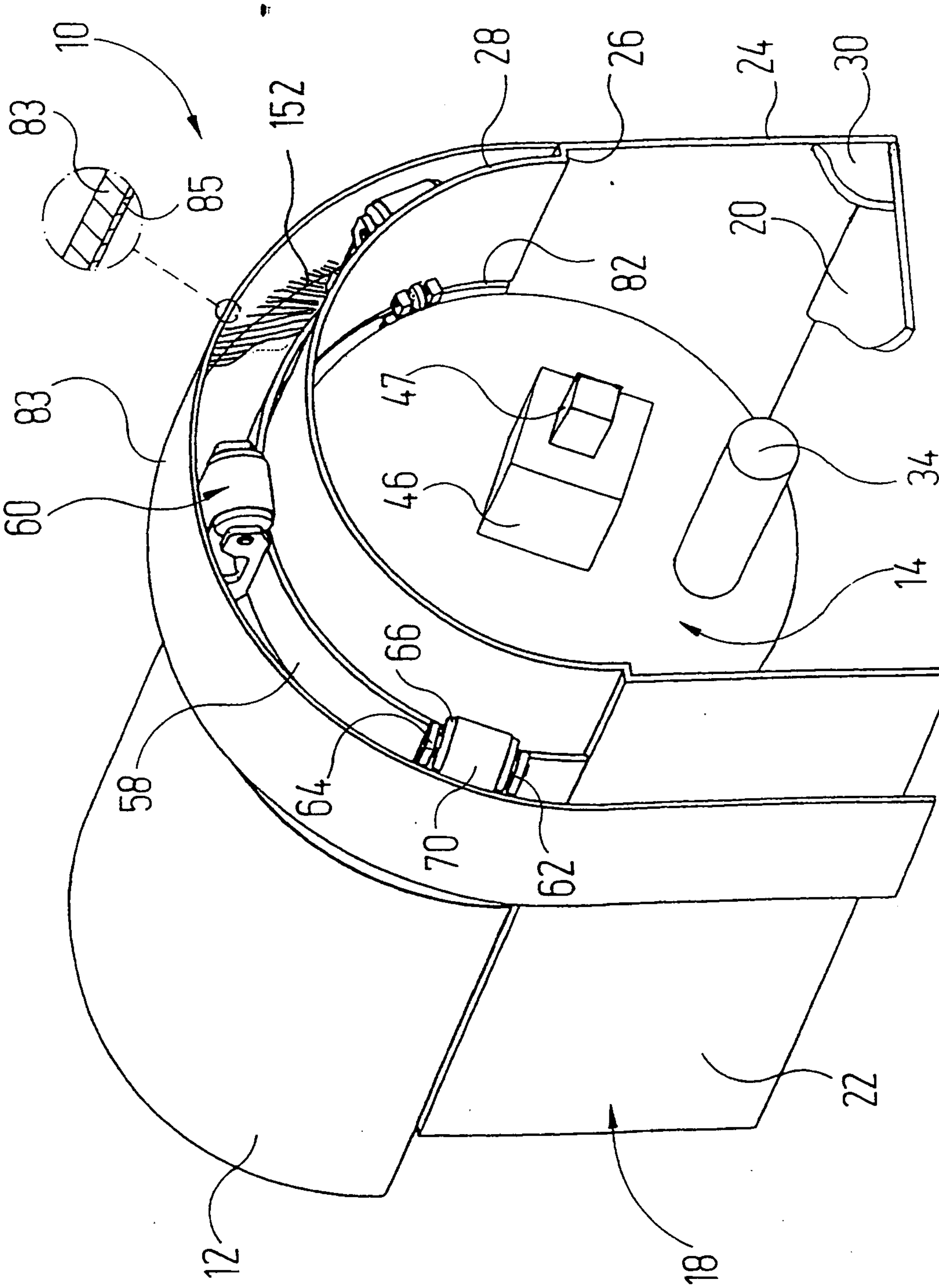

Fig. 2

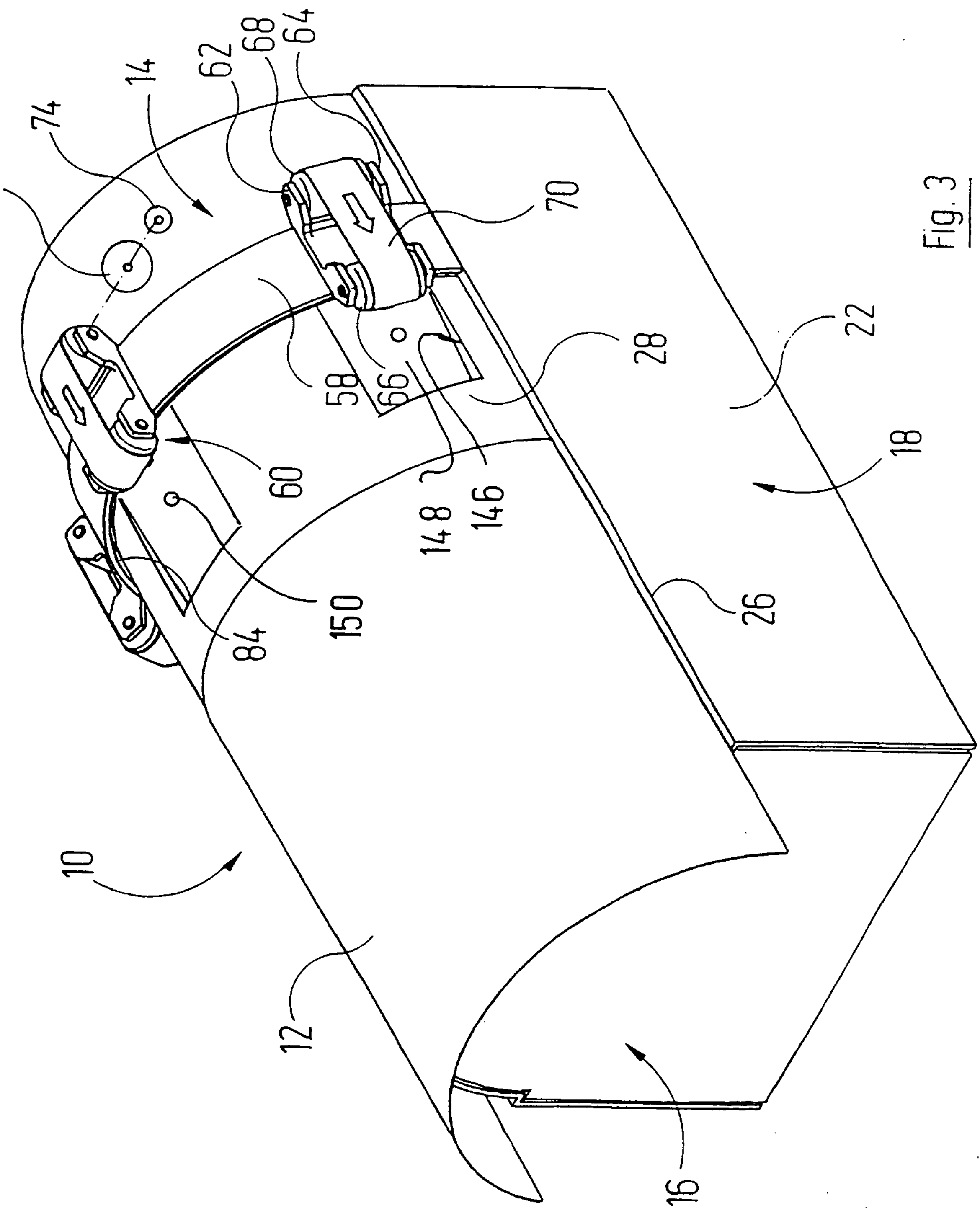

Fig. 3

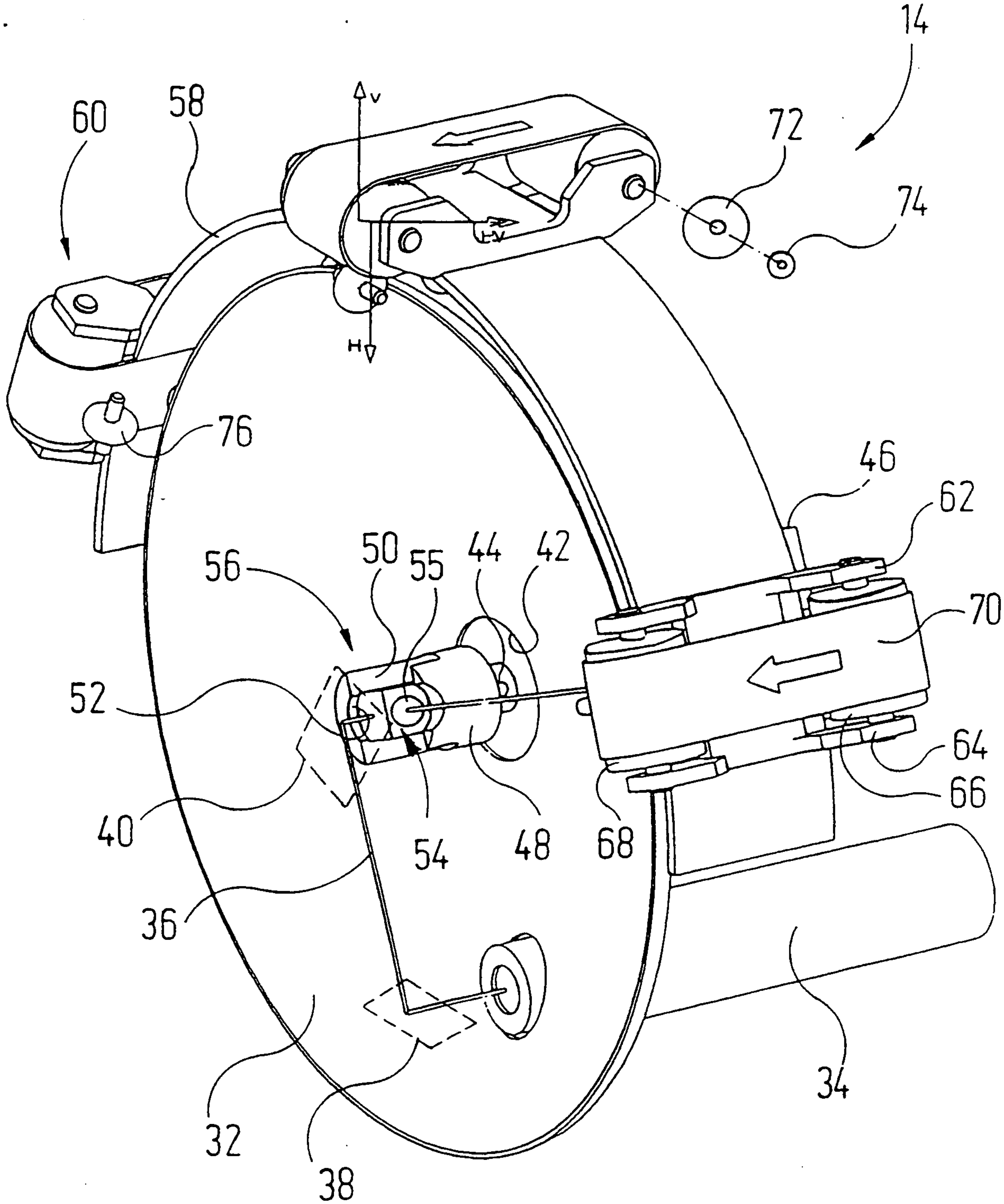
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Fig. 4

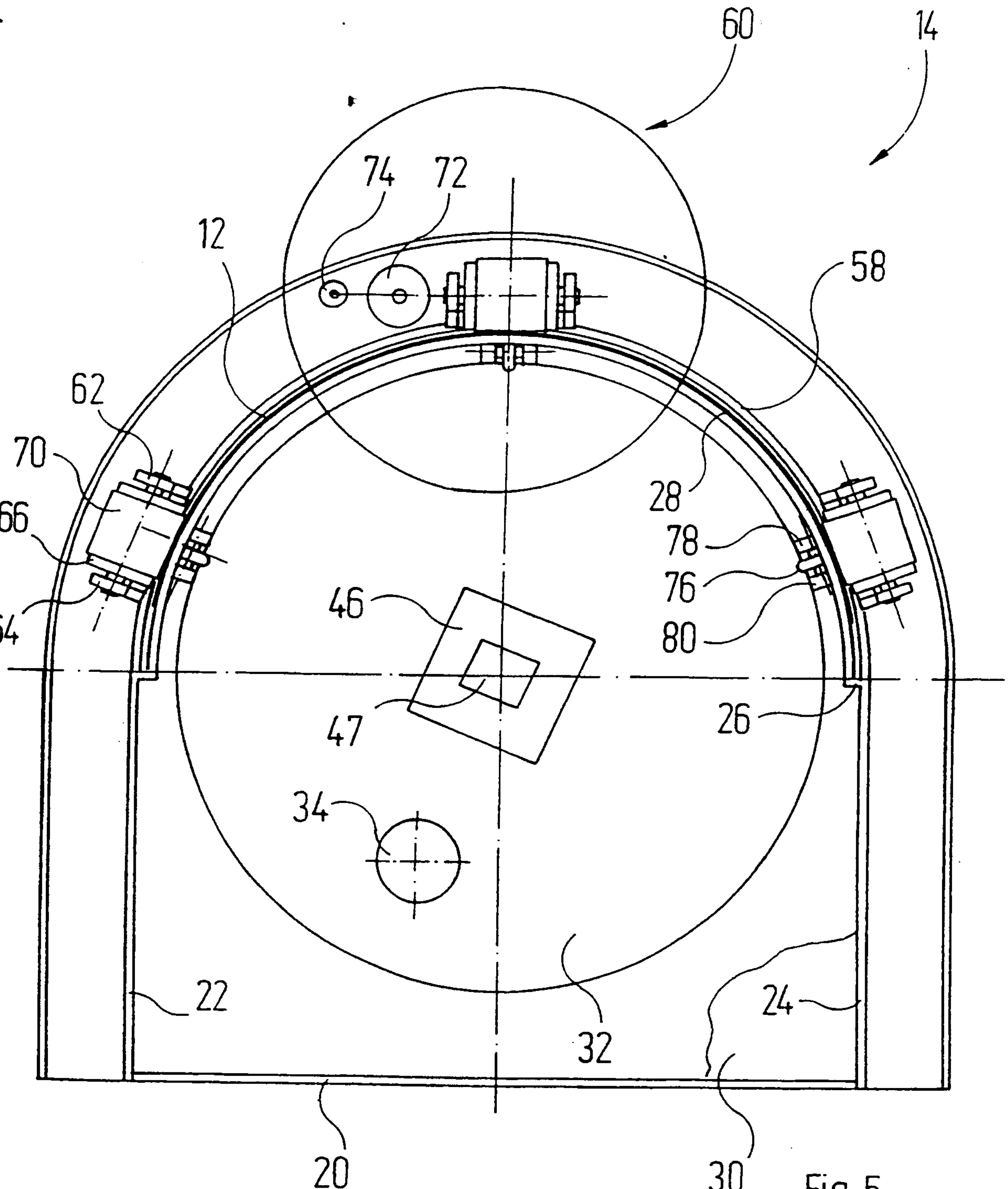

Fig. 5

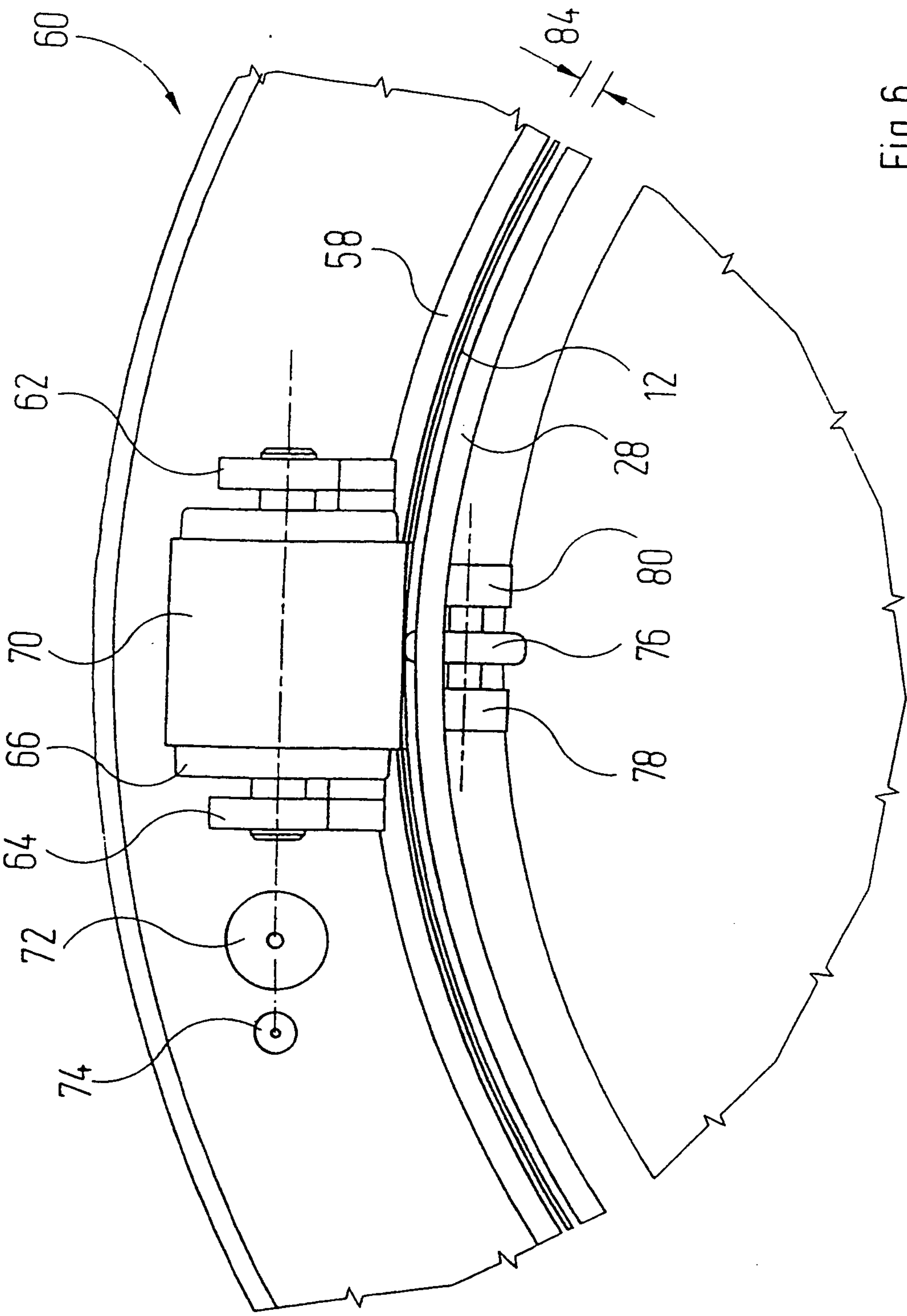

Fig.6

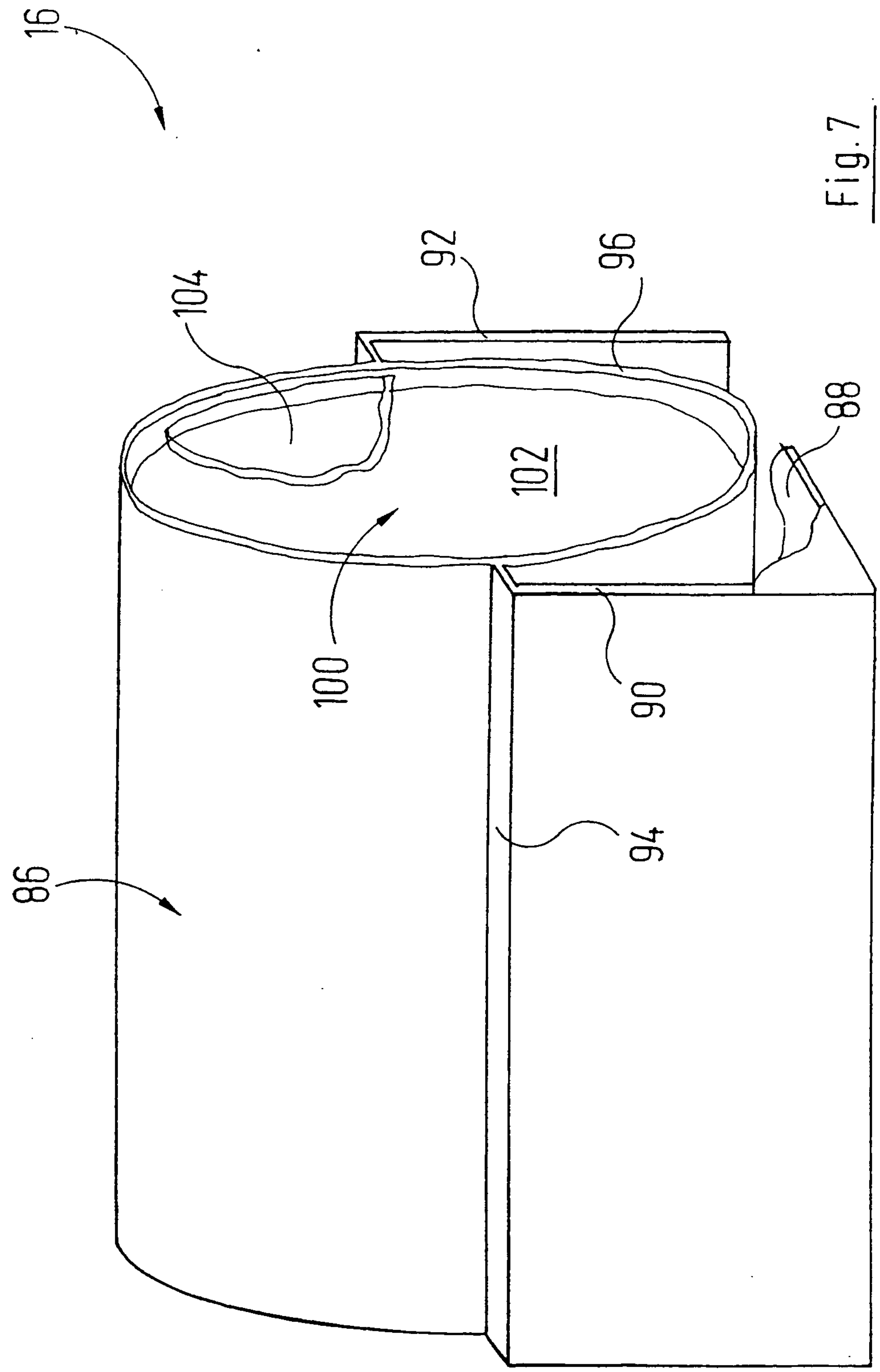

Fig.7

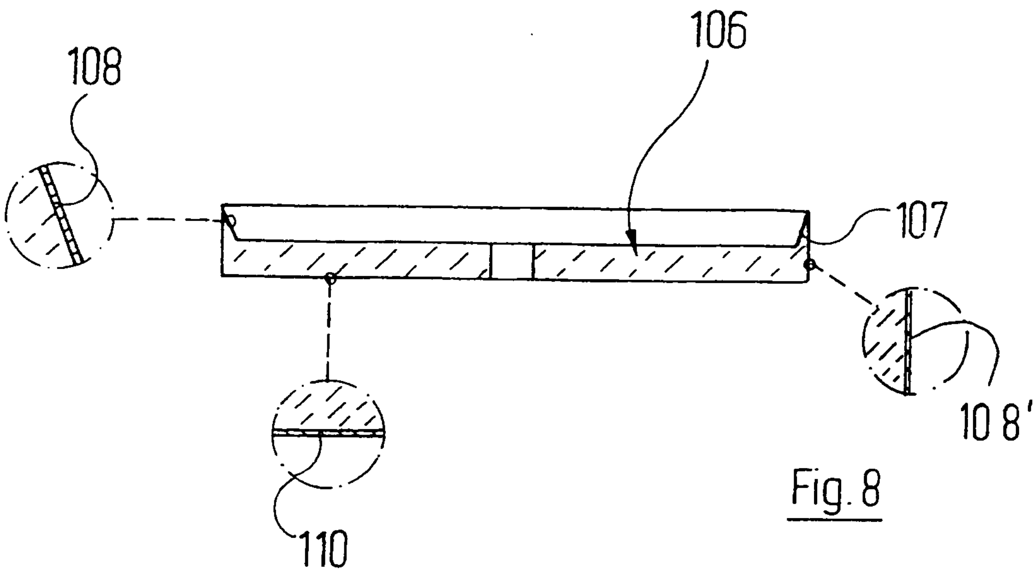

Fig. 8

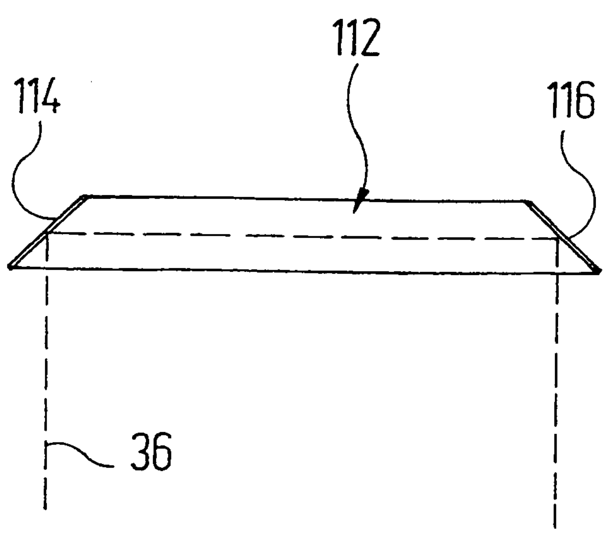

Fig.9

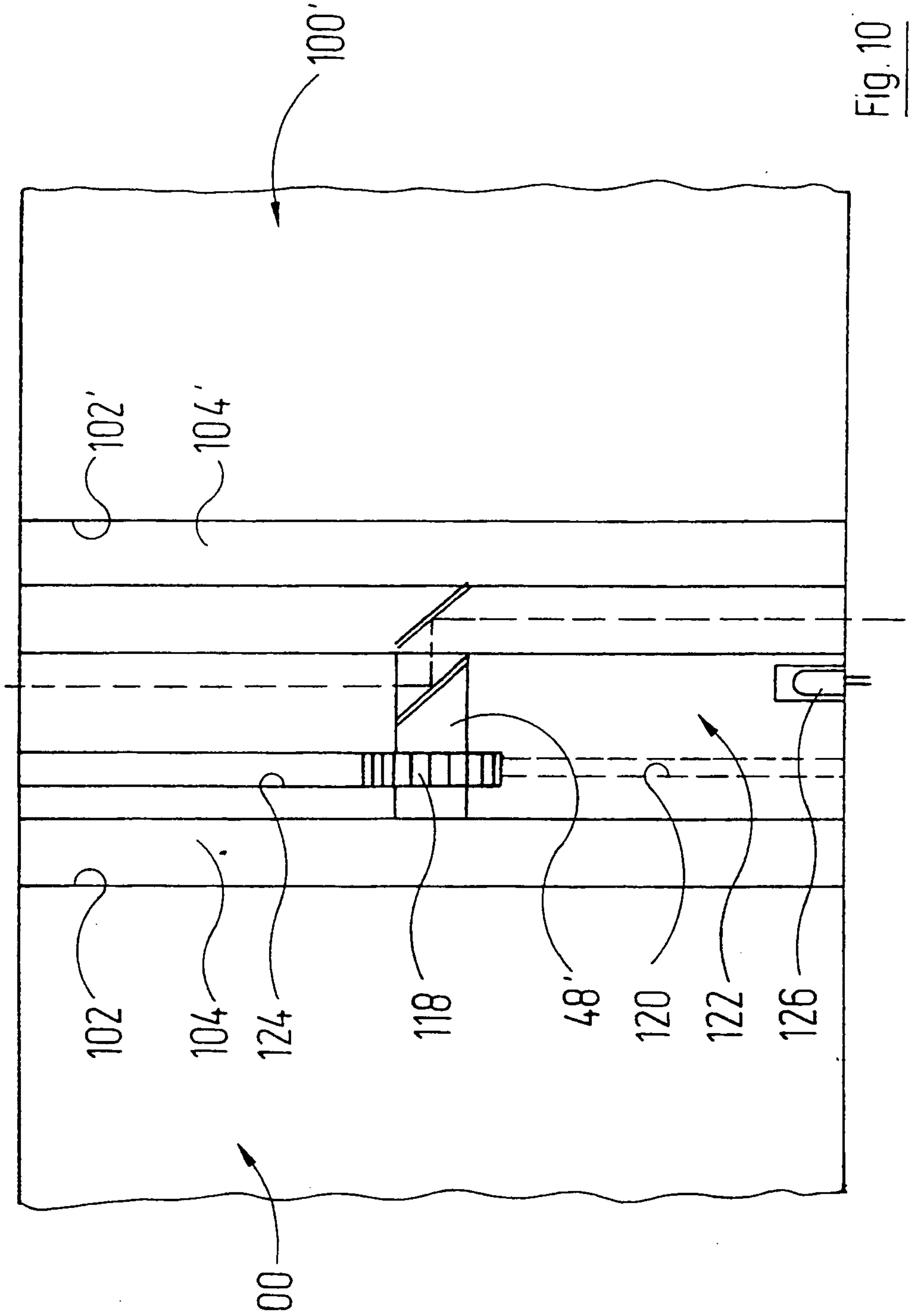

Fig. 10

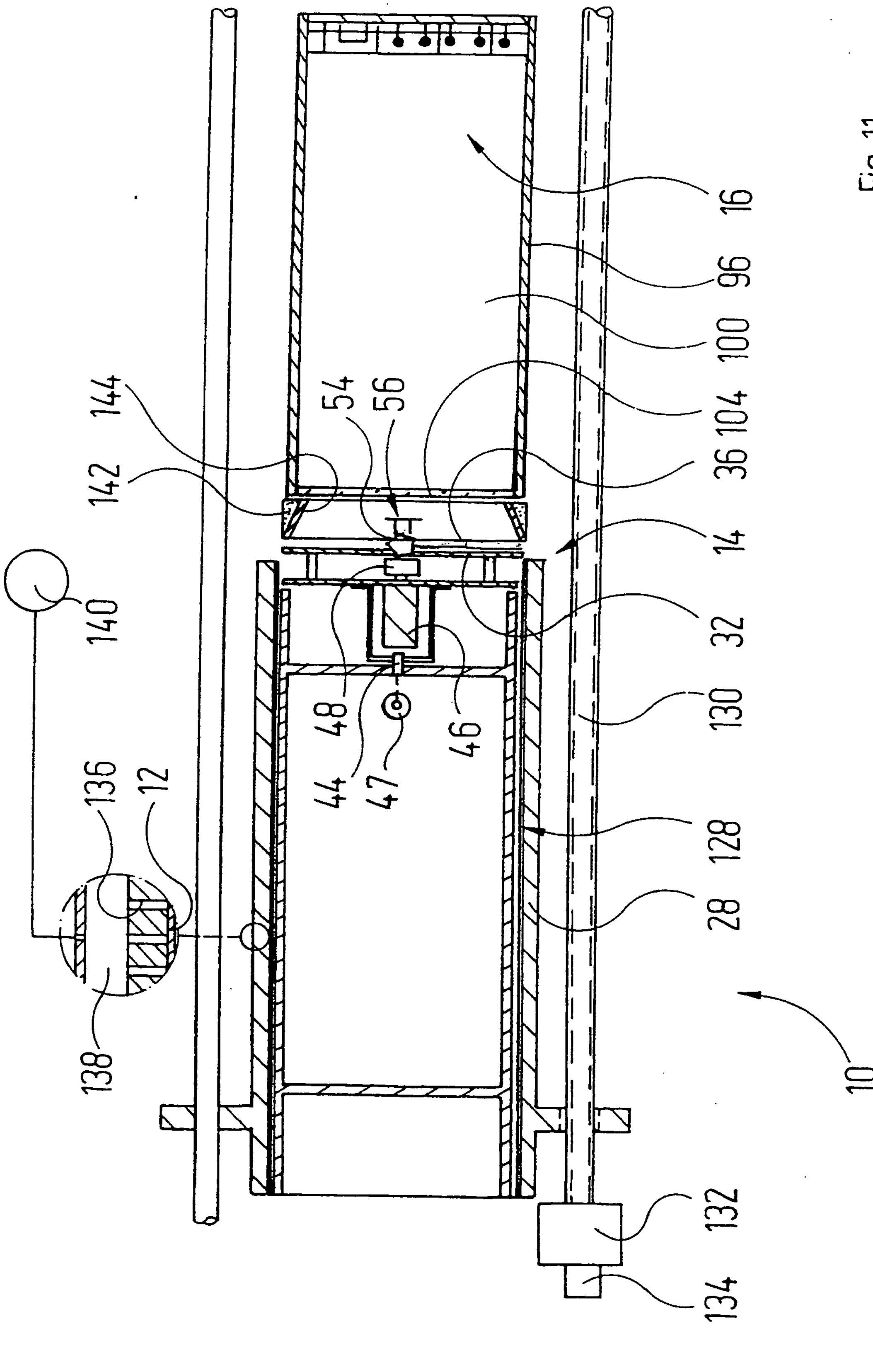
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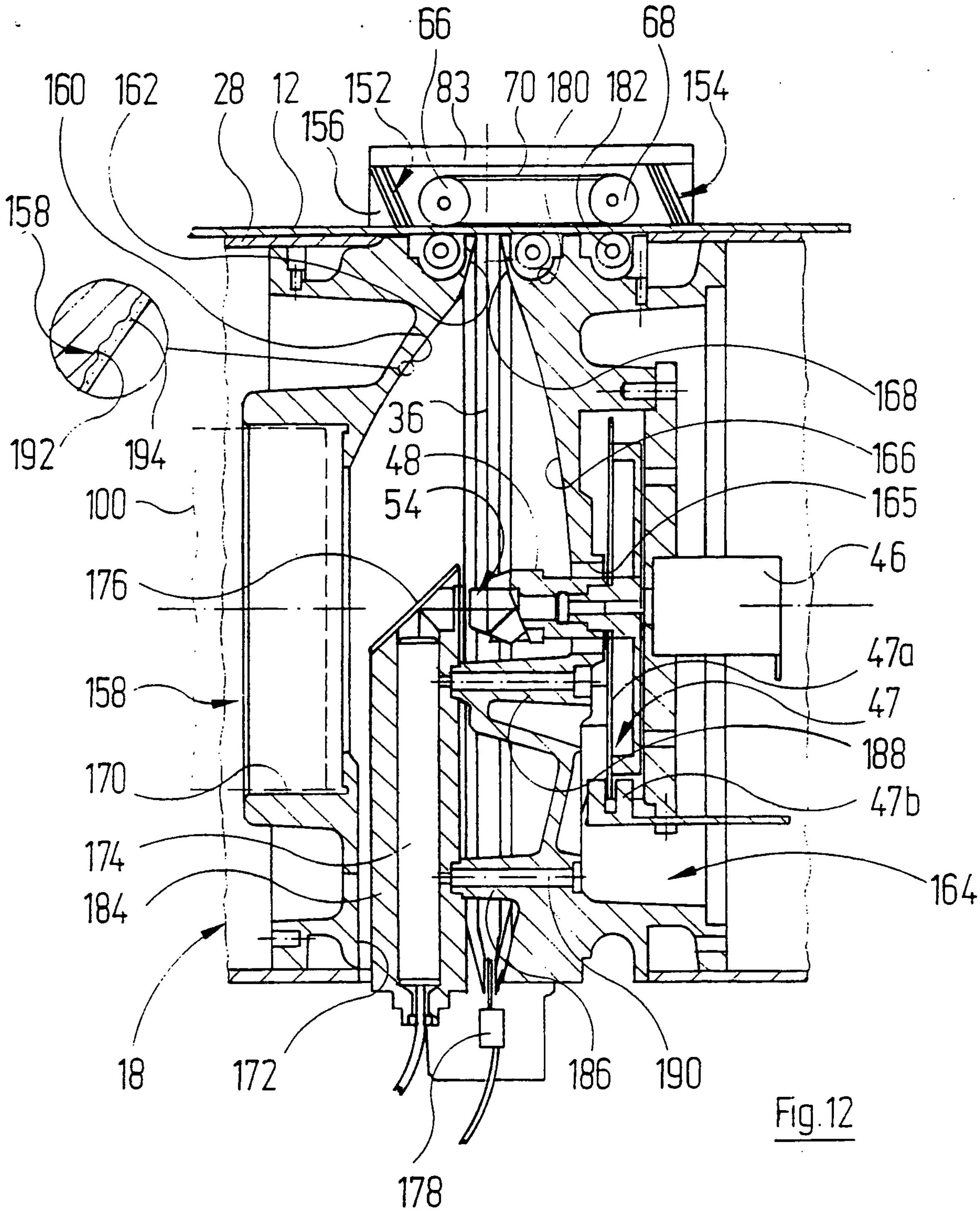
Fig.11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47a
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47b
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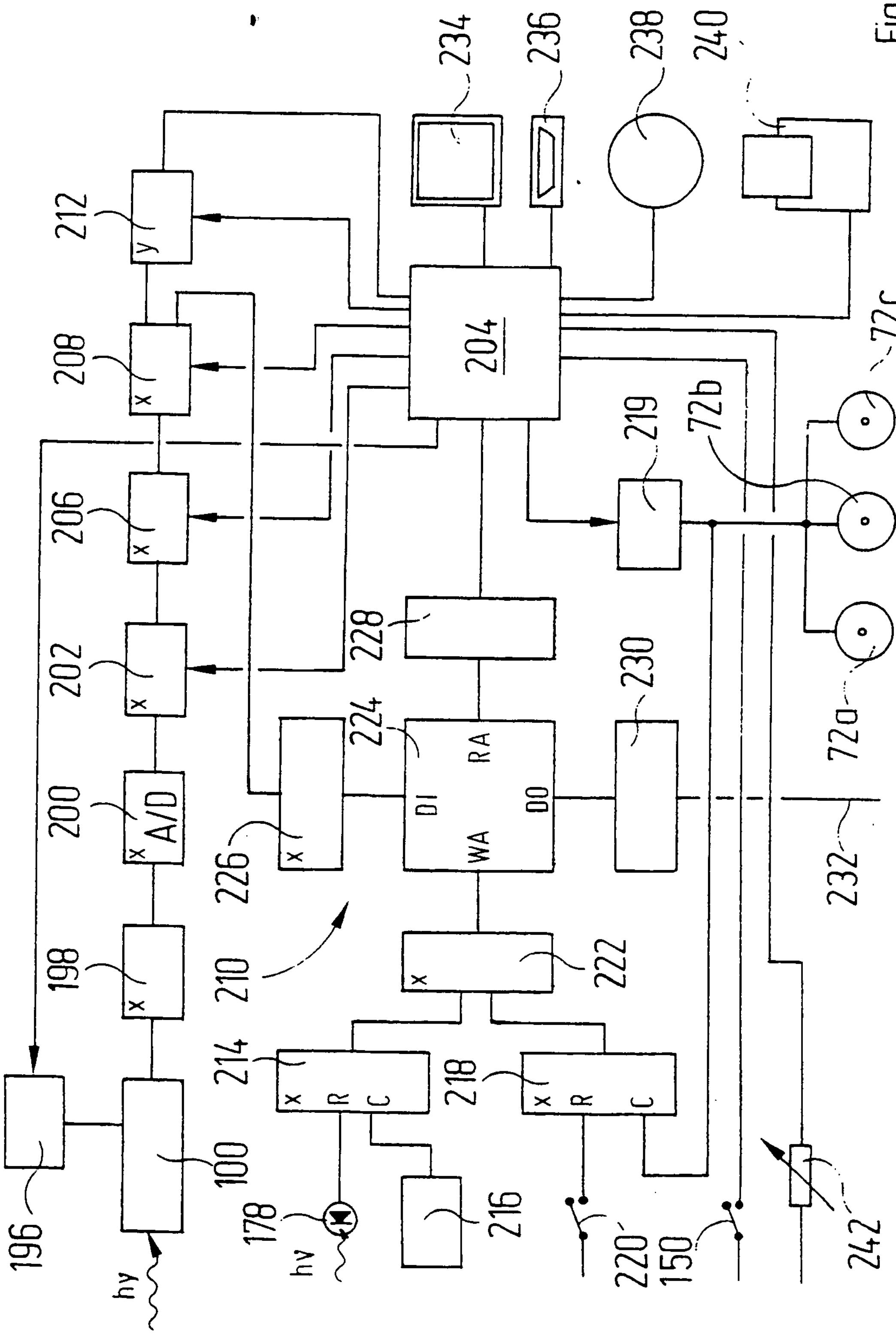
Fig.12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72a
72b
72c
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Fig. 13

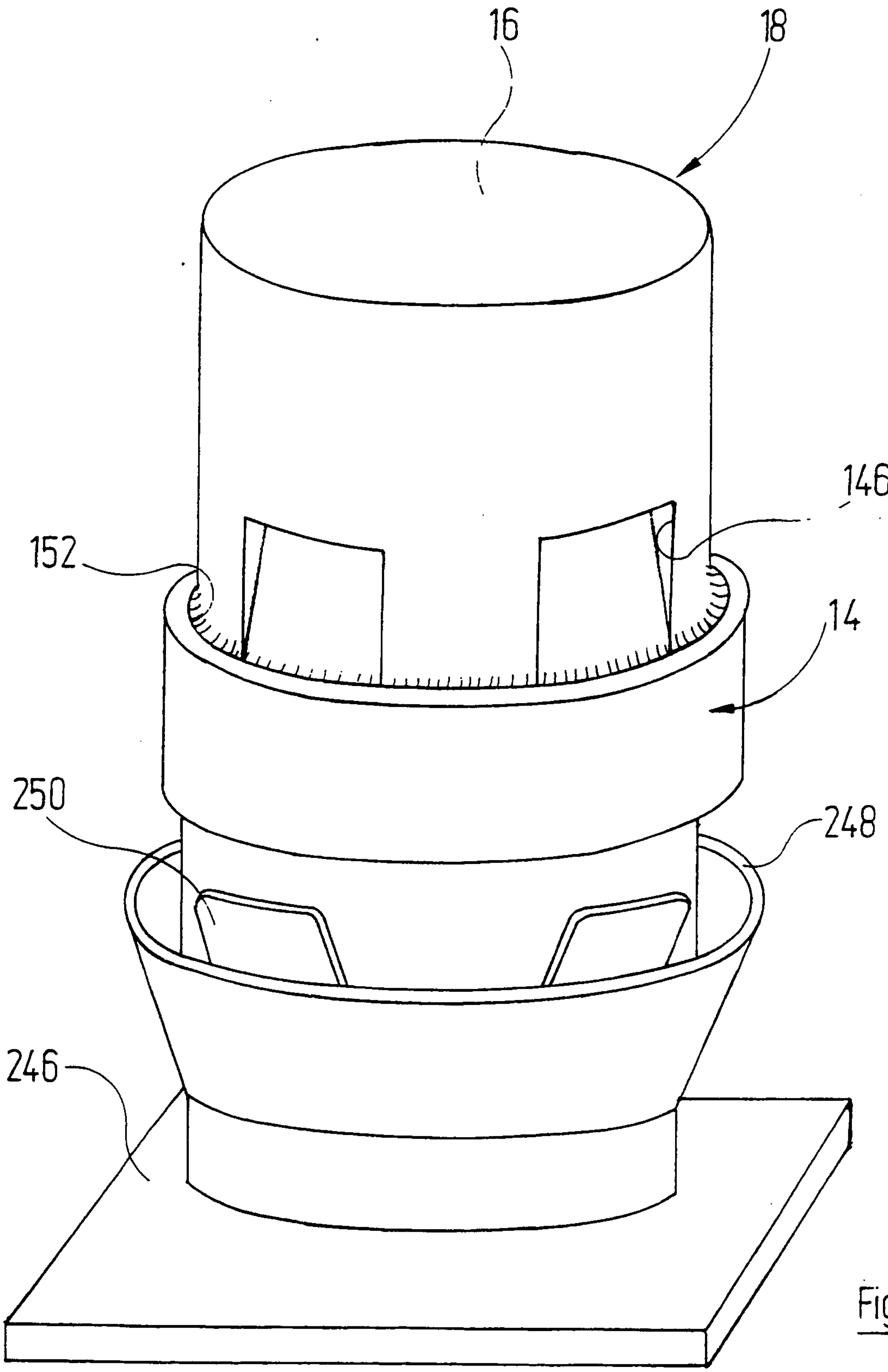

Fig. 14

INTERNATIONAL SEARCH REPORT

Inte   .onal Application No
PCT/EP 00/08604

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   G11B7/00   G01T1/29

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   G11B   G01T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 97 28486 A (ORION YHTYMAE OY ;RANTANEN MATTI (FI)) 7 August 1997 (1997-08-07) the whole document ---	1 2
X	EP 0 864 881 A (ORION YHTYMAE OY) 16 September 1998 (1998-09-16) the whole document ---	1
X	US 4 712 009 A (OHGODA MAKOTO ET AL) 8 December 1987 (1987-12-08) the whole document ---	1

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[X] Further documents are listed in the continuation of box C.   [X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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Date of the actual completion of the international search	Date of mailing of the international search report
16 February 2001	22/02/2001

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